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DEPARTMENT OF THE AR
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COMMERCE CITY, COLORADO

WATER MONITORING AT ROCKY MOUNTAIN ARSENAL
(A Review of the 360° Monitoring Program)

PREPARED BY:

GEOHYDROLOGY DIVISION
INSTALLATION RESTORATION DIRECTORATE

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TABLE OF CONTENTS

1. Introduction
2. History of Water Quality Monitoring at RMA
3. Evolution of the 360° Monitoring Program
4. Water Quality at RMA
5. Future of the 360° Monitoring Program
6. Summary
7. Appendix A - 360° Monitoring Program Sampling Schedule

ILLUSTRATIONS

Figure 1	360° Water Sampling Sites
Figure 2	Relative Distribution of DIMP in 360° Wells - Second Quarter, Phase II
Figure 3	Relative Distribution of DIMP in 360° Wells - Phase I
Figure 4	Relative Distribution of DCPD in 360° Wells - Second Quarter, Phase II
Figure 5	Relative Distribution of DCPD in 360° Wells - Phase I

TABLES

Table 1	Parameters for Sample Analyses
Table 2	360° Sampling Parameters
Table 3	Average DIMP and DCPD in 360° Water Monitoring Wells - Phase I
Table 4	DIMP and DCPD Levels in 360° Water Monitoring Wells - Phase II, Second Quarter

WATER MONITORING AT ROCKY MOUNTAIN ARSENAL

1. Introduction

a. The purpose of this paper is to provide summary information on the water quality monitoring program being conducted by the IR Directorate at RMA and to examine this information in terms of future program directions. Paragraphs 2 and 3 of the paper give a brief historical review of how the water quality monitoring program came about and its evolution into its present structure. Paragraphs 4 and 5 discuss the present program, the future trends, and the direction that the program should pursue.

b. The water quality monitoring program has as its principal aim to provide information as to water quality (concentration of contaminants) at selected on-post and off-post sites in response to a Cease and Desist Order issued by the State of Colorado; to provide additional information/indicators as to water quality and water levels appropriate for use in comprehensive survey contaminant identification and migration study; and to monitor for contaminants in groundwater flowing from sources off the Arsenal on to the Arsenal. Monitoring of water quality distribution may be used as one of the inputs into simulation modeling to predict future changes of groundwater quality as control measures are implemented (i.e., north boundary containment system).

2. History of Water Quality Monitoring at RMA

a. In May of 1975, two water sampling plans were initiated at RMA. One plan was in response to a series of lawsuits against RMA and Shell Chemical Company (SCC) by residents north of the Arsenal complaining of domestic water supplies. The other plan was in response to a Cease and Desist Order issued by the State of Colorado ordering that RMA and SCC stop contaminating the State waters of Colorado. Two months later, these two plans were melded into one, resulting in the establishment of 42 sampling sites on and off the Arsenal.

b. The design and implementation of this sampling scheme was carried out in coordination with the PM-CDIR and with the cooperation of SCC and the Colorado Department of Health. It was intended that these 42 sites would be sampled on a monthly basis for the 14 parameters shown in Table 1. In Oct 75, the Colorado Department of Health detected the presence of organic solvents and phthlate esters in isolated RMA well water samples.

c. The discovery of these organic compounds in well samples led to a major shift in the water quality monitoring program. It was felt that because these newly detected compounds are associated with materials available to the public, these contaminants detected in groundwater from RMA could come from sources off the Arsenal. The initial sampling program was restricted to the central and north part of RMA, as well as off-post to the north. In order for RMA to unequivocally declare what has been contributed to groundwater contamination, the antecedent water quality flowing on to the Arsenal had to be determined.

3. Evolution of the 360° Monitoring Program

a. The 360° water-monitoring program, which began in Jan 76, can be divided into two phases. Phase I of the program covers the period of time from the beginning of the program in January up to and including Oct 76. Phase II of the program covers the period of time since 1 Nov 76 up to the present time.

b. In Phase I of the program, 124 sampling sites, both surface and subsurface, were selected on the Arsenal. An additional 24 off-post sites, collected by the Tri-County Health Department, were also selected. Water samples from on-post were collected on a monthly basis, and analyses were by the Colorado Department of Health and SCC, as well as RMA (Table 2). The off-post samples were collected on a quarterly basis and analyzed by all three parties for the same parameters as on post.

c. In Aug 76, a review of the program was begun by PM-CDIR and RMA, with a view toward upgrading sampling procedures and methodology and upon analyzing the water sampling points with specific reference to groundwater samples. For many of the wells in use, the well bore logs were not complete; and in some instances, not maintained. In other instances, sampling wells were so close to each other as to be redundant. Sampling methods used required better quality control.

d. In terms of attempting to understand the groundwater-flow system at RMA and its relationship to contamination patterns, it is necessary to know as much as possible about the physical medium through which groundwater flows. Therefore, a good boring log of the subsurface conditions in which a well is set is necessary. Wells with multiple screens may provide variable water quality data because of the possibility for chemical stratification. Chemical stratification in groundwater is a common phenomenon and has been known to occur at RMA on the basis of early data results from the comprehensive survey. In order to arrive at consistent data, or to show that variations are in fact occurring, it is important that the same zones are sampled each time.

e. As a result of this coordinated PM-CDIR/RMA review, several changes in the water quality monitoring program were proposed. These proposed changes were submitted to Governor Lamm's Technical Review Committee (comprised of working representatives from RMA, Colorado State Health Department, and SCC) for comment and decision. These changes were approved by all interested parties and adopted by the Technical Review Committee. The result was the implementation of Phase II of the 360° water-monitoring program at RMA on Nov 76.

f. Phase II of this program established the Geohydrology Division as the principal element responsible for collection of water samples to be submitted to the Material Analysis Lab Division (MALD), IR Directorate, for analyses. The Geohydrology Division is also responsible for analyzing the data and verifying its accuracy prior to public release. This new 360° program set up 55 well sites and 12 surface sites on the Arsenal to be sampled on a quarterly basis beginning 1 Nov 76 (Appendix A). The off-post monitoring sites stayed essentially the same, utilizing 22 wells and 10 surface sites. Figure 1 shows the distribution of on- and off-post sampling sites. The responsibility for sampling the off-post sites remains with the Tri-County Health Department. The quality parameters analyzed in Phase II remain the same as in Phase I (Table 2). In addition to collecting water quality data on wells on a quarterly basis, Phase II also sets up a monthly water-level monitoring schedule.

4. Water Quality at RMA

a. Monitoring of water quality over relatively long periods of time is necessary to establish baselines to which changes can be compared and interpreted. For example, water quality may change with seasonal variations or other periods of time during which precipitation, run-off, and infiltration vary. Large variations of some chemical constituents, particularly in groundwater occur; therefore, monitoring over a period of time to establish baseline groundwater quality is necessary for the proper interpretation of apparent changes in that water quality.

b. Evaluation of potential contamination by measuring surface water quality is subject to more variables than groundwater. This is particularly true at RMA where many of the surface sampling points only contain water at intermittent times during the year. Extended dry periods followed by precipitation or extended rainy periods significantly affect water quality because of concentration and dilution effects. Groundwater, because it is much less subject to minor variations, tends to be more useful as a measure of water quality and the changes that may take place.

c. Data from Phase I of the 360° program has not been subject to the rigorous quality control that is being used in Phase II. Therefore, Phase I data has been chosen to use principally as background or indicator data and to establish a temporary baseline until Phase II has been evaluated for a longer period of time. For comparative purposes and because they are known contaminants from Arsenal operations, DIMP and DCPD have been chosen for comparison between Phase I (Table 3) and the second quarter of Phase II (Table 4). The second quarter of Phase II (31 Jan - 25 Apr 77) is used because the data for that quarter has all been received and verified.

d. The areal distribution of DIMP and DCPD in groundwater, based on the 360° wells, is compared between Phase I and second quarter Phase II in Figures 2, 3, 4, and 5. These maps are meant only to show the relative distribution of the two contaminants and no implication is intended as to their source or the actual groundwater-flow conditions resulting in their migration. The distributions shown, however, do indicate changes in the migration pattern. The concentration of DIMP (Figure 2) appears to increase towards the northwest boundary, as compared to the monitoring period covered in Phase I (Figure 3). The distribution of DCPD between the two periods also appears to show a slight shift towards higher concentrations over a wider area (Figures 4 and 5). The simulation modeling study by the USGS (digital model study of DIMP groundwater contamination at RMA by S. G. Robson in preparation) indicated that contamination of the groundwater is not continuous but moves through the system as discrete slugs. The data shown on Figures 2, 3, 4, and 5 would seem to support this conclusion. The highest DCPD concentration is shown as a continuous plume in Figure 5 (Phase I) and appears as two discrete units in Figure 4 (second quarter, Phase II). If these phenomena of discrete contaminated slugs of groundwater do in fact occur, then the need for additional monitoring becomes absolutely necessary. On the other hand, it may be that the monitoring program has not been in existence long enough to understand the kinds and degrees of variation that may occur naturally. It is common practice in groundwater studies to monitor water quality and water level changes over three to five years so that seasonal and other fluctuations can be accumulated and analyzed. The 360° water-monitoring program has only been in existence less than two years, and the data recorded is not sufficient to warrant any firm conclusions. In addition, the lack of a rigorous quality control program during Phase I limits the utility of that part of the data base.

e. It again must be stressed very strongly that the contamination patterns shown on these maps are based on present 360° wells. The presence or absence of other, as yet undetermined, areas of contamination is not implied. Present distribution of monitoring wells, particularly toward the northwest part of the Arsenal, is not sufficient to evaluate potential concerns regarding groundwater contamination located there. The same can be said for other parts of the Arsenal where the well distribution is sparse. Whether groundwater contamination from a source is continuous or occurs in discrete units requires both longer monitoring time and additional wells. The 360° program needs a longer period of time to establish necessary baselines. In addition, the program is being continuously evaluated and additional monitoring wells have been identified and are being installed as time and manpower permits.

5. Future of the 360° Monitoring Program

a. In terms of the northern part of the Arsenal, the extent of pollution of groundwater has been reasonably defined. Because of the Cease and Desist Order which directed attention to the north boundary area, most of the 360° wells are located in the north and central part of the Arsenal; so that other areas of contamination, if they exist, still need to be identified. The present monitoring program, in conjunction with work being done in the comprehensive survey task, will help to better define the groundwater-flow system and, in turn, identify these other areas of contamination.

b. Groundwater chemistry data, particularly from Phase I has been used in simulation modeling efforts by the USGS. The DIMP transport model developed by S. G. Robson of the USGS used Phase I data. A more recent simulation model for the pilot containment system used data in part from Phase II. The reliability of simulation models of groundwater flow systems and its water quality are dependent upon the accuracy of the impact data and the assumptions made to calibrate the model. A more comprehensive input on water quality can only improve such a model, which can then be used as an input into contaminated source and area treatment plants.

c. Finally, any water quality treatment operations undertaken at RMA require monitoring of changes in water quality and water levels.

d. The 360° water-monitoring program will be an integral function of IR activities at RMA until contamination of water flowing under and across the Arsenal is deemed no longer to be the result of Arsenal activities. Details of the program, however, may change as the informational needs change. Sampling points may be added or deleted; and the frequency of sampling, as well as the types of analyses, will reflect changes needed in the program to provide maximum information.

6. <u>Summary</u> - In summary, two tasks should be examined in the immediate future as the 360° monitoring program progresses. These are as follows:

a. The requirement for future analysis so as to determine the need and specific location for a denser network of monitoring wells designed to fill in existing data gaps.

b. Evaluation of reliability of existing wells as representatives of the true character of groundwater quality and, where warranted, the upgrading of the wells.

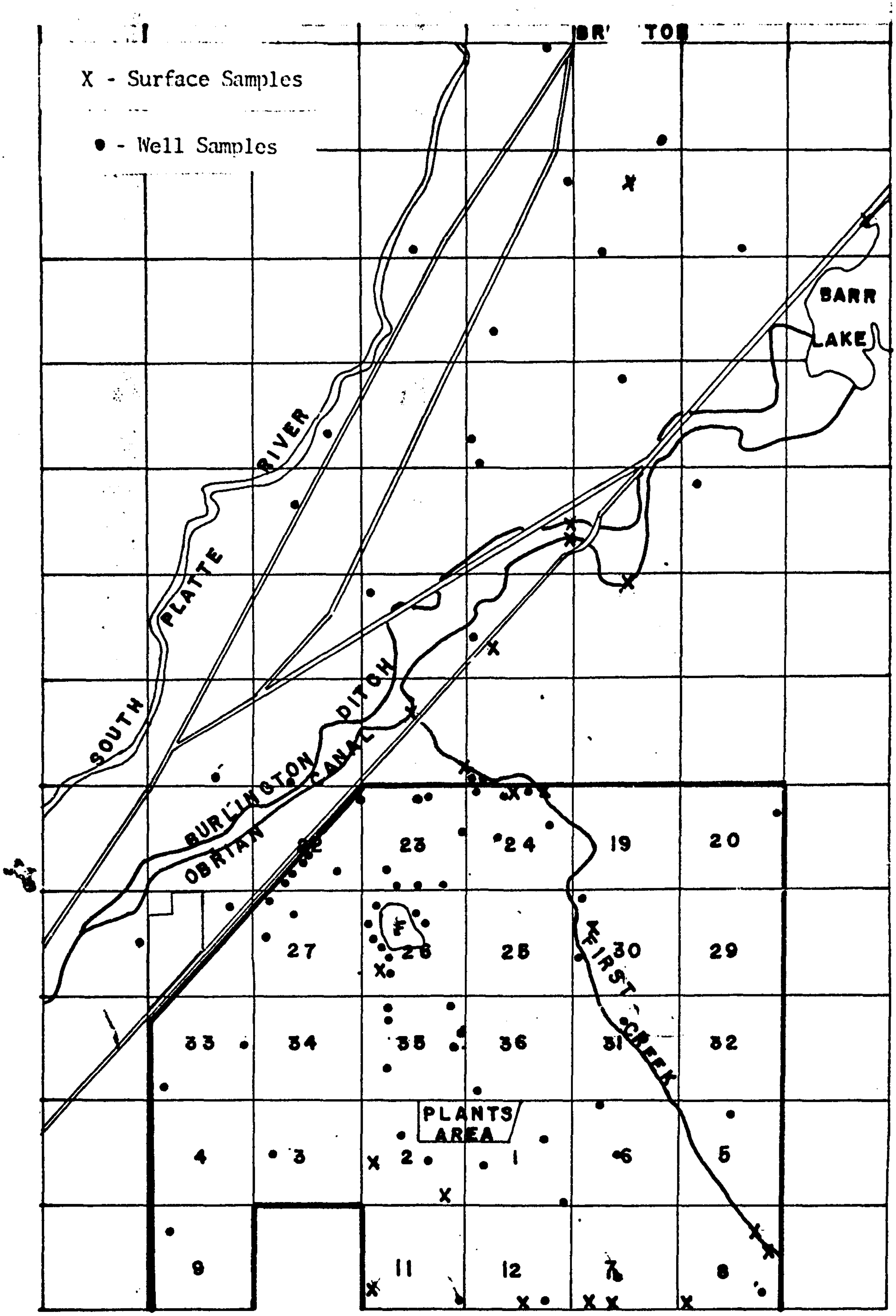

FIGURE 1 360° WATER SAMPLING SITES

FIGURE 2

RELATIVE DISTRIBUTION OF
DIMP IN 360 WELLS –
2ND QTR – PHASE II

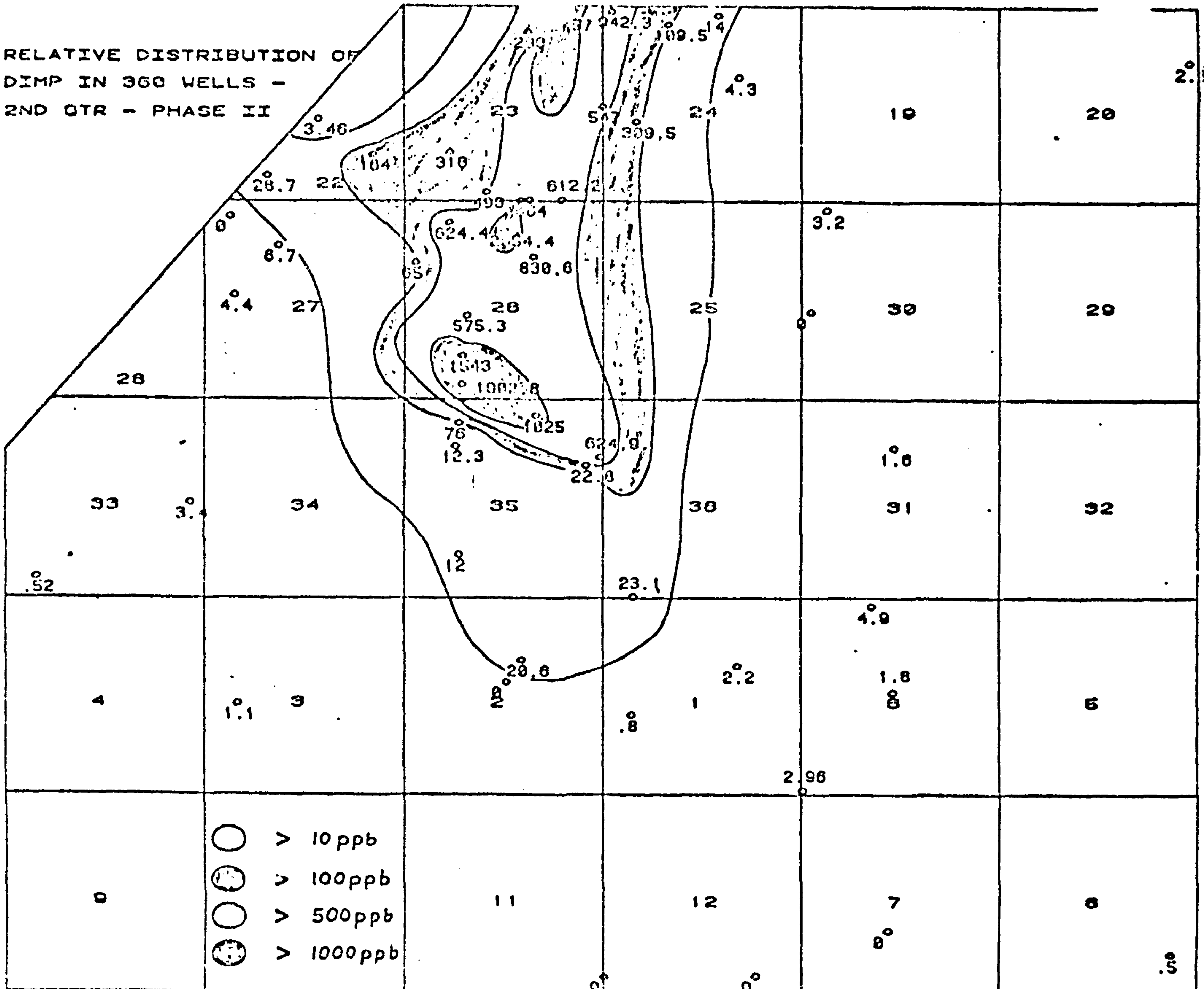

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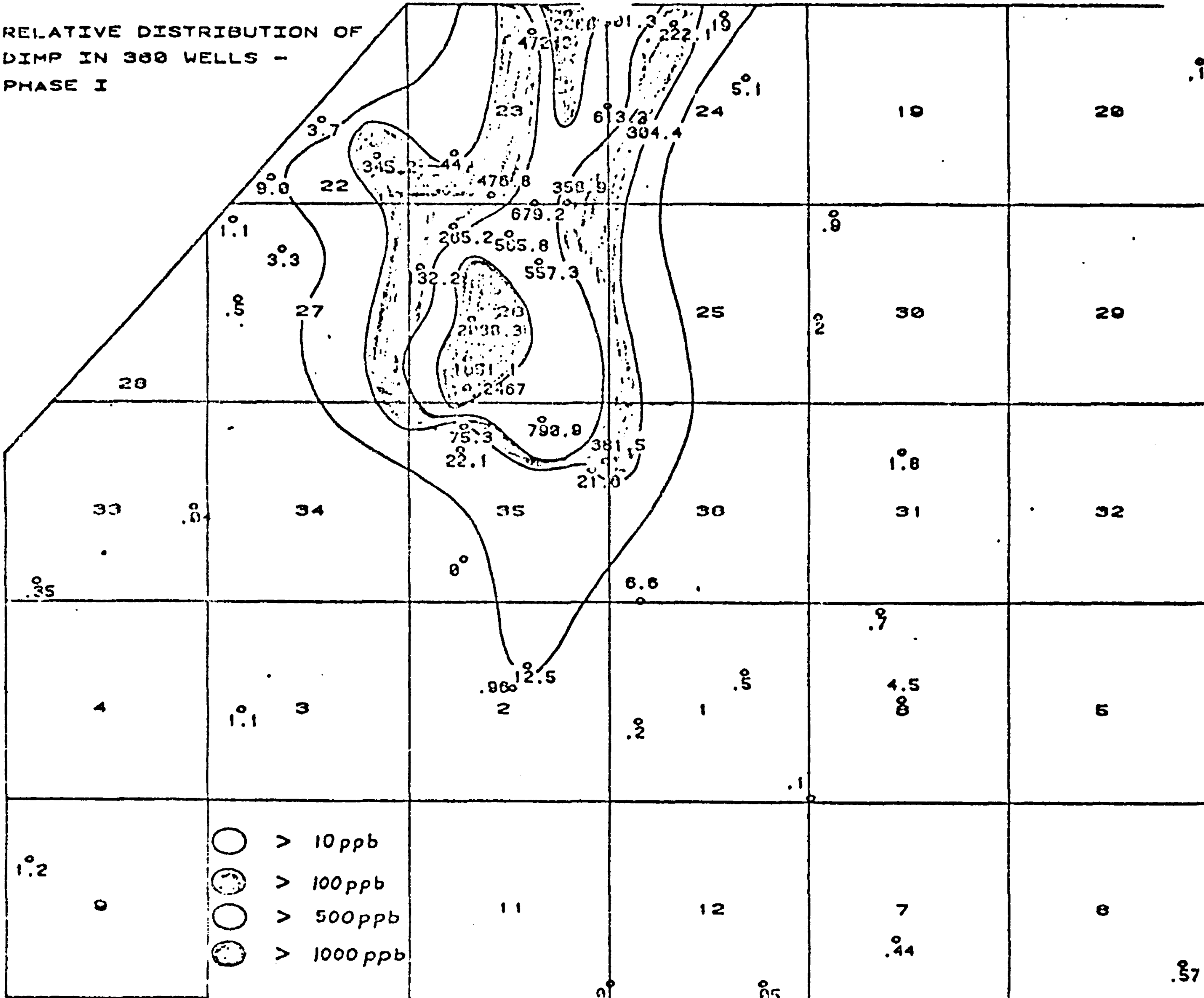
FIGURE 3

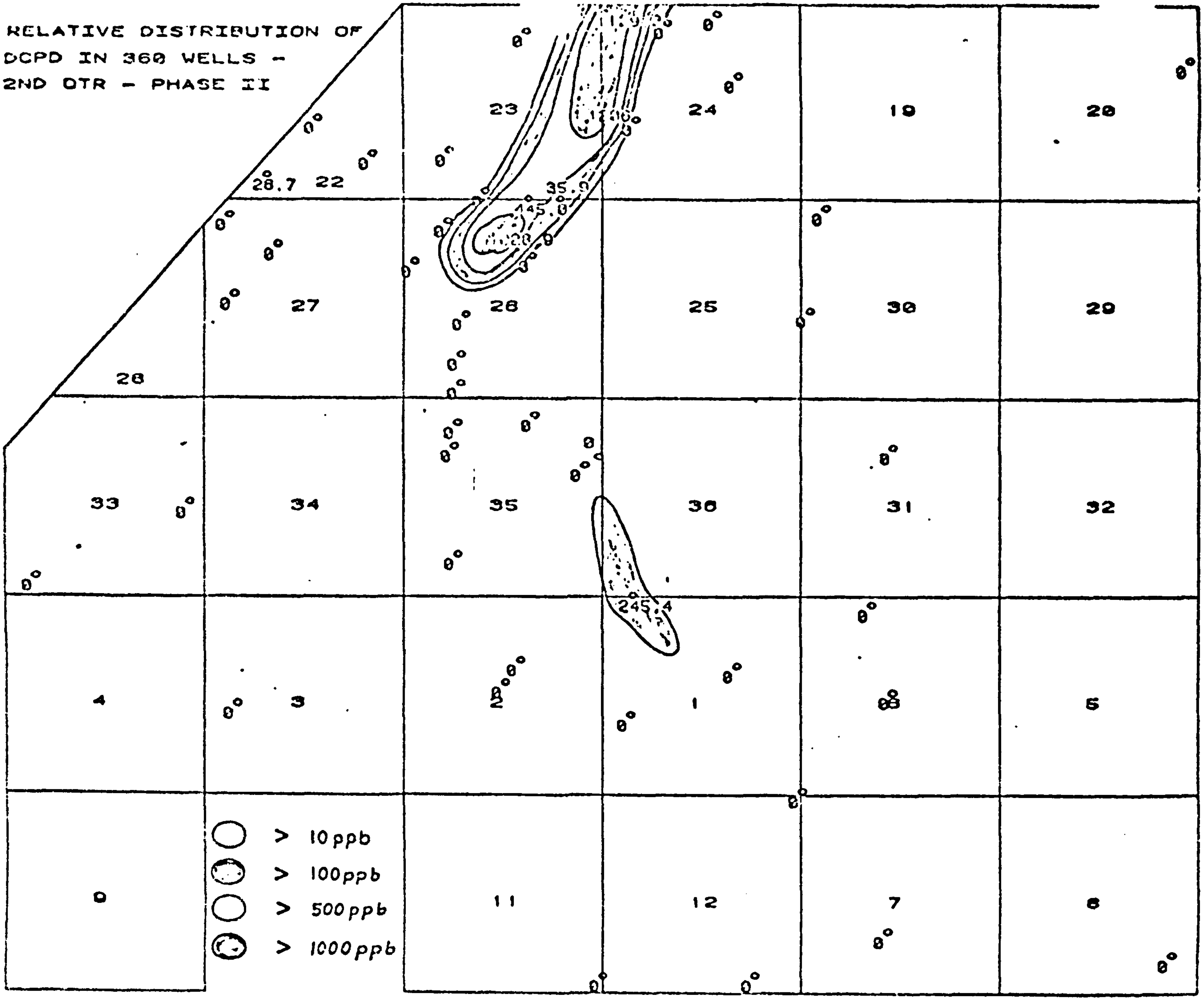
RELATIVE DISTRIBUTION OF
DIMP IN 380 WELLS –
PHASE I



VIEWGRAPH #3

FIGURE 4

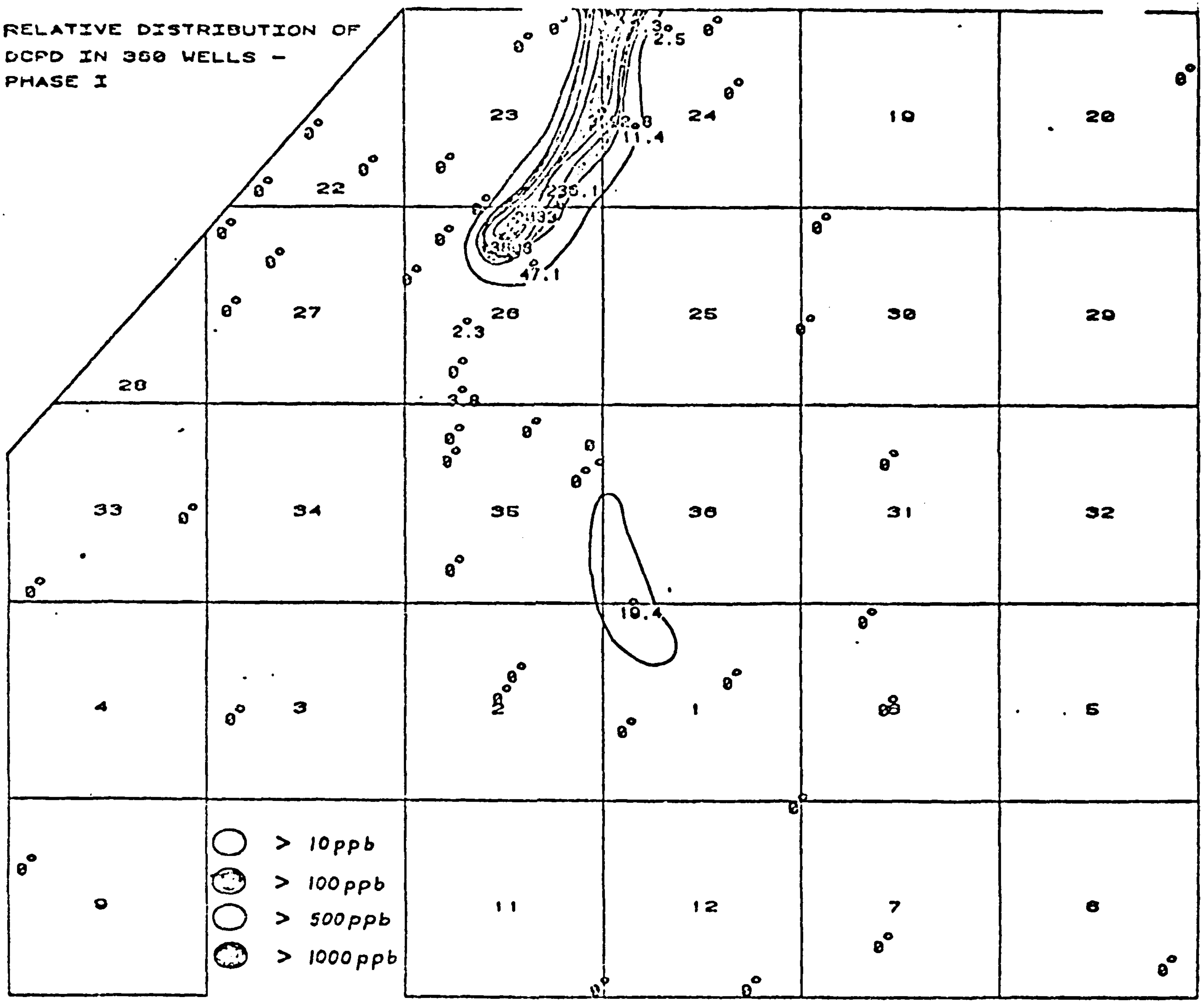
RELATIVE DISTRIBUTION OF
DCPD IN 360 WELLS –
2ND QTR – PHASE II



VIEWGRAPH #16

FIGURE 5

RELATIVE DISTRIBUTION OF
DCPD IN 360 WELLS –
PHASE I



VIEWGRAPH #5

TABLE 1. Parameters for Sample Analyses

Parameter	RMA	CDH	SCC
Aldrin		X	X
Chloride	X	X	
DCPD	X	X	X
Dieldrin		X	X
DIMP	X	X	X
Endrin		X	X
Fluoride	X	X	
Nitrate/Nitrite	X		
pH	X	X	
Sodium		X	
Sulfate	X	X	
TOTAL Hardness	X	X	
Chlorate	X	X	
Copper	X	X	

TABLE 2. 360^{o} Sampling Parameters

Parameter	RMA	CDH	SCC
pH	X		X
DCPD (Odor Elim)	X	X	X
DIMP	X	X	
Chlorinated Hydrocarbons (i.e., Aldrin, Dieldin, Endrin)		X	X
Total Hardness	X		
Sodium	X	X	
Sulfate	X		
Chloride	X		
Conductivity		X	
Nitrate/Nitrite	X	X	
Dissolved Solids		X	
Chlorate		X	
Fluoride	X		
Phosphate		X	
Total Phosphate		X	

TABLE 3 Average DIMP and DCPD in
360° Water Monitoring Wells - Phase 1

Well No.	DIMP			DCPD		
	Avg	Min	Max	Avg	Min	Max
2	345.21	15	825	0	0	0
6	21.58	4.0	92	0	0	0
9	.49	0	3.25	0	0	0
10	.09	0	1.9	0	0	0
13	.22	0	1.5	0	0	0
15	0	0	0	0	0	0
17	22.05	10.3	1.4	0	0	0
20	1.82	0	14	0	0	0
21	.68-	0	3.2	0	0	0
22	.20	0	2.75	0	0	0
23	12.54	6.4	16.7	0	0	0
24	.49	0	4.5	0	0	0
25	472.27	260	1700	0	0	0
33	.44	0	2.2	0	0	0
34	.05	0	.6	0	0	0
35	0	0	0	0	0	0
37	1.09	0	9.9	0	0	0
38	.04	0	.62	0	0	0
41	2088.3	1111	3937	2.25	0	27
45	222.08	120	305	2.48	0	18
46	4.48	0	52	0	0	0
47	.13	0	1.9	0	0	0
49	1.15	0	5.2	0	0	0
50	.35	0	1.8	0	0	0
51	.57	0	6.0	0	0	0
60	901.25	96.2	1481	3512.5	2033	8679
62	265.21	190	310	0	0	0
65A	381.5	81	630	2.13	0	17
71	44	44	44	0	0	0
72	476.8	253	726	0	0	0
73	557.26	310	809	47.1	10	106
78	5.08	2.2	9.2	0	0	0
79	.90	0	13	0	0	0
93	1851.1	1380	2450	0	0	0
99	3.3	.9	8.4	0	0	0
103	1.10	0	9.5	0	0	0
104	9.01	.7	83	0	0	0
105	3.67	2.5	4.7	0	0	0
109	.96	0	4.5	0	0	0
115	613.3	390	1044	3592.8	1942	11774
118	555.8	171	2200	3803.0	1160	6827
119	19	31.2	30.4	0	0	0
121	2066	221	5000	0	0	0
122	304.4	212	555	11.35	0	41
125	256.7	103	370	1.03	0	13
126	6.35	0	19.5	19.4	0	54
132	679.2	199	799	2035	1120	4959
133	355.91	247	520	256.13	59.5	690

Well No.	DIMP			DCPD		
	Avg	Min	Max	Avg	Min	Max
139	75.3	54	87	0	0	0
141	2467	1400	3724	3.87	0	46.[illegible]
142	132.2	34	299	0	0	
145	790.0	512	1094	0	0	
[illegible]58 Post	1390	942	1700	0	0	0
84	8.68	3.7	15.4	0	0	0
IV	3.46	2.2	5.7	0	0	0
VI	.10	0	.6	0	0	0
VIII	4.72	2.64	6.5	0	0	0
XII	8.25	2.59	19.2	0	0	0
XIX	93.10	13.8	194	0	0	0
XX	19.94	3.6	89.4	0	0	0
XII	50.8	0	178	0	0	0
XXIV	.12	0	.7	0	0	0
XXV	0	0	0	0	0	0
[illegible]III	1.17	0	4.4	0	0	0
XXXI	0	0	0	0	0	0
XXXII	0	0	0	0	0	0
LIII	262.8	57	628	14.4	0	49
LIV	1119.4	717	1074	2074	1320	2556
LV	32.2	18.4	40	0	0	0
LVII	75.5	0	115	0	0	0
LVIII	1.27	0	2.5	0	0	0
LVIX	25.95	20.7	32	0	0	0
LVXI	1.04	0	2.7	0	0	0
LXIII	5.5	0	12	0	0	0
LXIV	.17	0	.69	0	0	0
Boilers	84.32	60	104	0	0	0

TABLE 4 DIMP and DCPD Levels in 360° Water Monitoring Wells - Phase 2, Second Quarter

Well No.	DIMP	DCPD
2	164	0
6	22.8	0
9	2.23	0
10	2.96	0
13	0	0
15	12	0
17	12.29	0
20	1.64	0
21	4.93	0
22	0.8	0
23	20.57	0
24	4.38	0
25	290	0
33	0	0
34	0	0
35	0	0
37	1.07	
38	3.44	0
41	575.3	
45	109.47	0
46	1.77	0
47	2.34	0
50	.52	0
51	.54	0
60	942.31	1129.23
62	624.37	0
65A	624.92	0
71	316	0
72	490.78	0
73	830.6	
78	4.33	0
79	3.16	0
98	1543	0
99	6.74	0
103	0	0
104	28.7	
105	3.46	0 0
109	0	0
115	547	- 1206
118	2954.35	1028.89
119	14	
121	2457	
122	309.5	0
126	23.07	245.43
132	664	445.02
133	612.16	35.93
139	76	0
141	1902.82	0
142	65	0
145	1025	0
Off 58		
Post		
84		
IV	5	0
VI	1	0
VIII	5.6	0
XII	8.2	0
XIX	99	0
XX	4.9	0
XXI	49	0
XXIV	0	0
XXV	0	0
XXVIII	0	0
XXXI	0	0
XXXII	0	0
LIII		
LIV	1021	2141
LV	40	0
LVII	43	0
LVIII	1.4	0
LVIX	29	0
LVXI	4.7	
LXIII	.5	0
LXIV	0	0
Boilers	41.7	0